Production of bioenergy and food products from renewable sources: Omega-3 fatty acids and H_2 gas, using microalgae grown on CO_2 (a greenhouse gas)

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Objectives

The project has three parts: 1) the set up of a renewable biological platform (i.e., microalgae) grown on greenhouse gas (e.g., CO_2) for the production of energy-rich or food products, such as hydrogen gas and Omega-3 fatty acids; 2) the determination of substrate consumption rates and of productivities for added-value products, and, 3) the transfer of the platform to course 10.28 (part of the Energy Minor), in the Fall.

Background

Microalgae can be effective to remove CO_2 from the atmosphere while being the source of proteins, carotenoids, pigments and vitamins, lipids and gas, for applications in the food, feed, cosmetics, pharmaceutical and bio-fuel industries. Culture conditions (e.g., medium composition, illumination stress) can have a major impact on algae characteristics (Yangüez et al., 2015). Microalgae can accumulate significant amounts of desired products. For example, *Nannochloropsis* species contain 30% proteins and 20% fatty acids, on a dry weight basis (Grimi et al., 2014).

The lead student will have the opportunity to do process research in bioenergy, focusing on the production of lipids from microalgae, and the production of hydrogen, and to design a two-stage process batch or batch/continuous process.

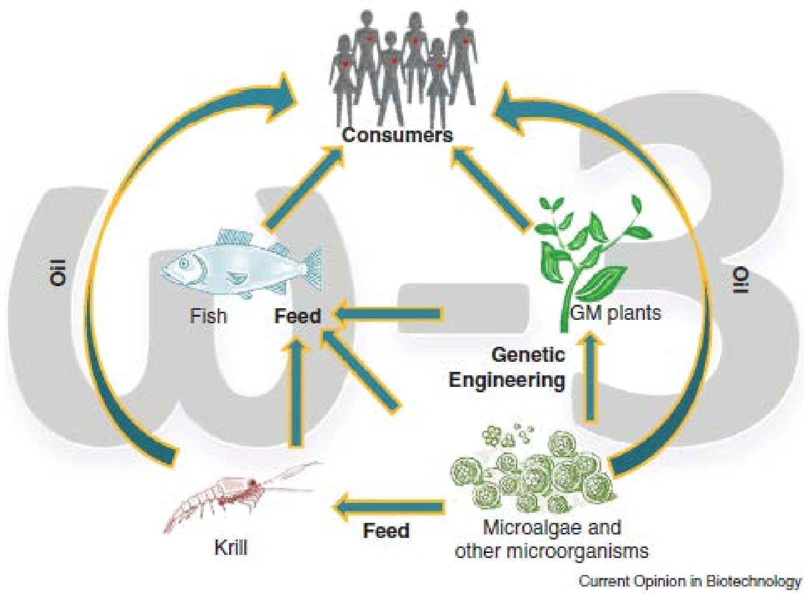
This project is part of a program for developing sustainable energy processes of industrial and manufacturing relevance. A company focusing on Omega-3 fatty acids and H_2 gas will provide us with their genetically-engineered mictoalgae and share their experience with it. They are especially interested in the use of Chlamydomonas reinhardtti

Last year, the U.S. consumed approximately 6.95 billion barrels of petroleum products, an average of 19 million barrel/day (eia.gov 2015). This consumption has significant environmental consequences including those caused by oil spills and extraction, fine particulates and hydrocarbon emissions which can lead to serious respiratory problems. Also, 21 pounds of CO_2 are produced for every gallon of refined gasoline burned.

The production of bio-oil by fermentation using waste or renewable sources (e.g., glycerol, ligno-cellulosic biomass) or of useful energy sources by photosynthesis (e.g., H_2) from captured CO_2 can offer potential solutions to the problem.

BIO-OIL FOR FOOD OR BIODIESEL

Docosahexaenoic acid (DHA) is a polyunsaturated fatty acid belonging to the so-called omega-3 group. DHA has attracted much attention because of its beneficial effect on human health. At present, fish oil is the major source of DHA, but alternatively it may be produced by use of microorganisms that can contain large quantities of DHA and are considered a potential source of this important fatty acid.



Several heterotrophic microalgae have been used as biofactories for omega-3 fatty acids commercially, but there is a strong interest in using autotrophic microalgae as both biofuel crops and the development of omega-3 fatty acids, such as DHA.

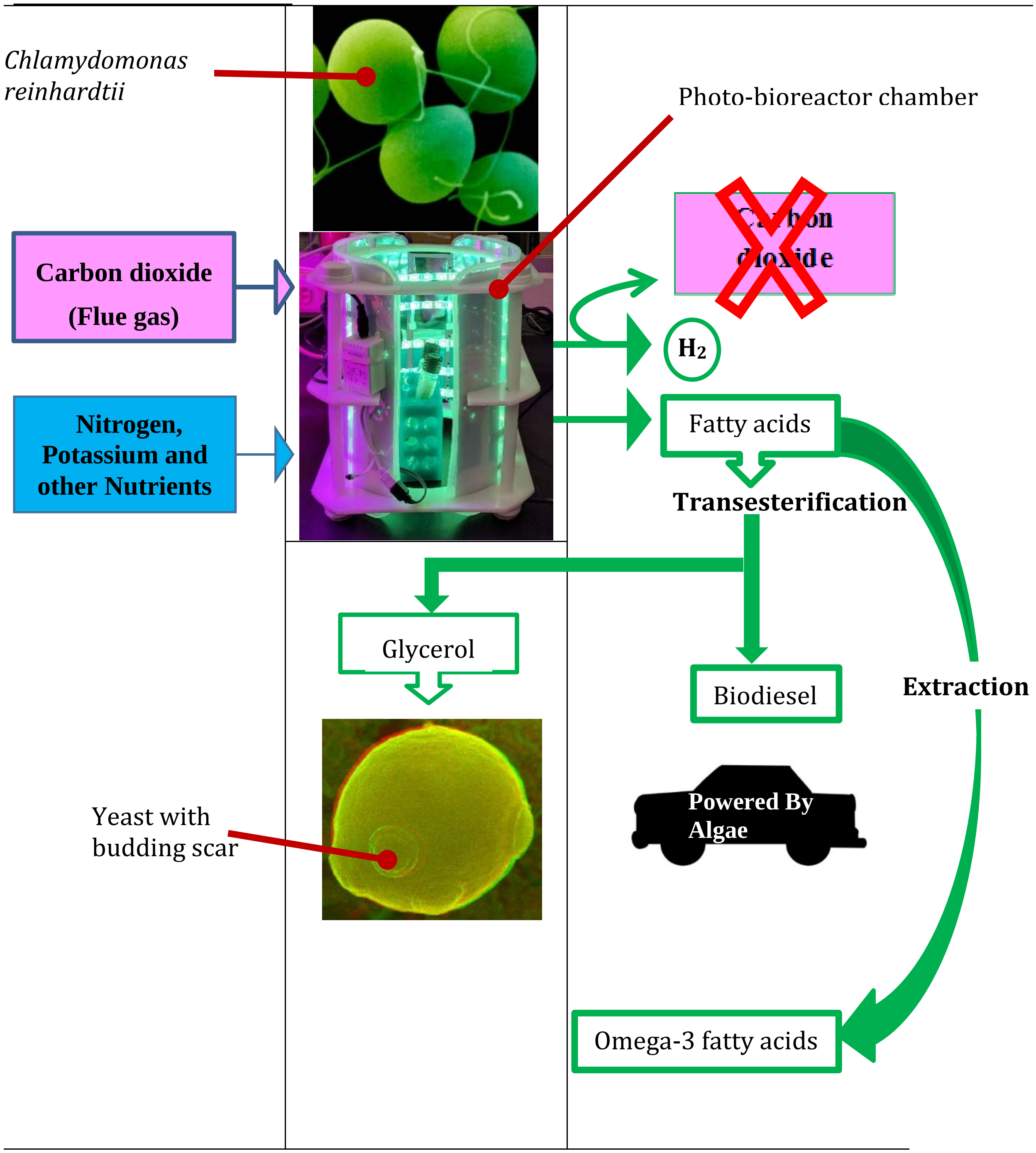
Microalgal fatty acids can also be used for making biodiesel in a sustainable way. Biodiesel burns somewhat cleaner than traditional diesel fuel Biodiesel is a cleaner-burning renewable fuel and its use can reduce greenhouse gas emission by 57% to 87% when compared to petroleum diesel (Biodiesel.org 2015). Biodiesel has the ability to be more environmentally sustainable because it can be made from renewable feedstock, including recycled cooking oil, soybean oil, animal fats, and microorganisms such as microalgae. However it has not made the transition to a majority fuel source because an economically feasible solution has not yet been discovered to meet the needs of the high demand of commercial production. Only 0.34 billion barrels of the 6.95 billion barrels consumed by the U.S. last year were biodiesel (eia.gov 2015).

HYDROGEN PRODUCTION

Currently, only 20% of global energy is provided as electricity, while 80% is provided as fuel. Hydrogen (H_2) is the most advanced CO_2-free fuel and provides a 'common' energy currency as it can be produced via a range of renewable technologies, including photovoltaic (PV), wind, wave and biological systems such as microalgae, to power the next generation of H_2 fuel cells.

Microalgae production systems for carbon-based fuel (oil and ethanol) are now at the demonstration scale, and microalgal technologies are evaluated for the commercial production of solar-driven H_2 from water.

Bioenergy theme: H_2 gas co-produced with fatty acids for food/health care applications through environmentally-friendly process using microalgae sequesting CO_2. Waste product glycerol is fed to yeast for creating high-value added products.



A yeast/microalgae platform will be set up this summer for the proposed research, and include the photobioreactor shown above (for the microalgae).

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